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The Effect of Event Rarity on the Perception of Correlationally Indeterminate Data

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14. ABSTRACT

Previous research has indicated that events that are rare are more informative than common events. The present study manipulated event rarity through social stereotypes to evaluate event rarity's role in the perception of correlationally indeterminate data. Social stereotypes were used as a means to manipulate expectations about which observations would be considered rare and which common. Participants were presented with a correlationally indeterminate sample and were asked to rate the correlational relationship in the population from which the sample was drawn. The results did not support the event rarity hypothesis but were consistent with confirming hypothesis testing behavior. Further research is ongoing to evaluate what factors may influence differential behavior (e.g., preference for common over rare observations and vice versa) in the perception of correlationally indeterminate data.

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Introduction

The ability to detect relationships in the environment is essential and underlies other cognitive processes such as categorization and stereotype formation. Crocker (1981) described correlational knowledge as essential to our ability to “explain the past, control the present, and predict the future” (p. 272). There is a large literature investigating how people determine correlational and causal relationships. Two prevailing approaches to understanding this ability are inferential and traditional. By an inferential approach, people attempt to “determine the likelihood that there is a relationship between the variables” (McKenzie & Mikkelson, 2007). In contrast, the traditional perspective asserts that people summarize the information and observations available to them. Some recent studies (Griffiths & Tenenbaum, 2005; Kelley, Anderson, & Doherty, 2007; McKenzie & Mikkelson, 2007) have focused on demonstrating evidence for an inferential approach over the traditional approach in that the inferential approach can explain findings in the correlation and causation perception literature that the traditional viewpoint cannot.

The current study evaluated causal judgments in the context of social beliefs. Ongoing work at USAARL is evaluating biases and errors in causal judgment in Soldiers after periods of sleep deprivation. It is hypothesized that Soldiers who are sleep deprived will show strong dependence on previous beliefs (including social beliefs) to form a present judgment. Overweighting prior beliefs and knowledge has been shown to significantly increase the likelihood of judgment errors in predicting future events. Thus, understanding the role that prior beliefs have in causal judgment under “normal” conditions allows for comparison to performance under conditions of stress (or, specifically, sleep deprivation). The ongoing work was designed to test predictions made by the event rarity hypothesis and positive test strategy as a result of the outcome of this study.

Military significance

Causal judgment and covariation detection is important to military operations such as intelligence analysis (Heuer, 1999). If these abilities are compromised then soldiers and other military personnel are more likely to make potentially major errors in judgment such as accurate prediction and precautionary actions. It is predicted that under situations of high stress, causal judgments weigh heavily on prior expectations and beliefs as suggested by the adaptive component to the inferential approach and McKenzie and Mikkelson’s (2007) event rarity theory. It should be noted that this study was conducted at Bowling Green State University as a follow-up to the first author’s doctoral program and was not a USAARL project. The study serves as a basis for current USAARL projects conducted by the primary author.

Background

Typically, observations in a covariation assessment task of dichotomous variables are summarized using a contingency table which has four cells; Cell A is the presence of both variables, Cell B and Cell C correspond to the presence of one variable and absence of the other,

and Cell D is the absence of both variables (figure 1). The cells of the table are used to calculate the generally accepted measure of correlation between dichotomous variables, delta P, the formula for which is shown in Equation 1.

$$\Delta P = A/(A+B) - C/(C+D) \tag{1}$$

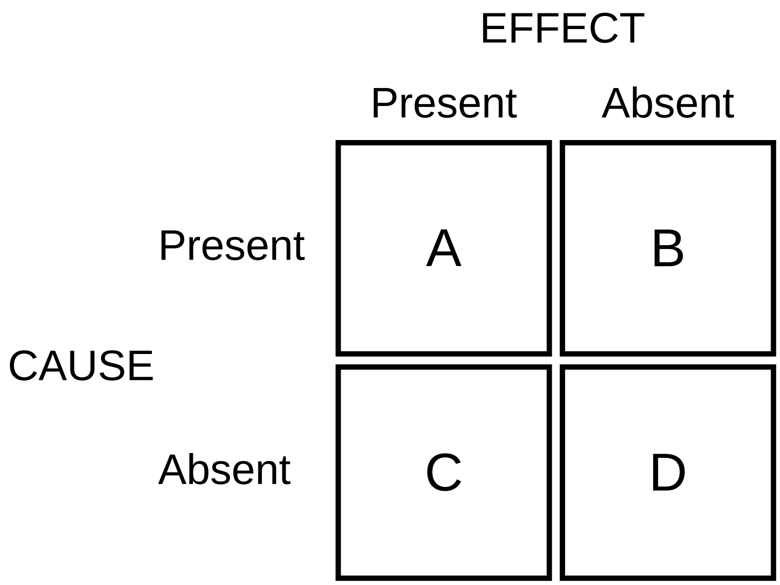

Figure 1. A contingency table representing the components of delta P applied to a causal scenario. Each cell represents the frequency of observations.

A number of studies have shown that people find the cells to be of unequal importance in covariation assessments such that Cell A is the most important, followed by Cell B and Cell C, and Cell D is the least important; A > B ≥ C > D (e.g., Levin, Wasserman, & Kao, 1993). While this finding has been discussed previously as evidence that non-normative processes are occurring (e.g., Kao & Wasserman, 1993), McKenzie and Mikkelson (2007) are the first, as far as the authors are aware, to use an inferential approach to explain this finding. Specifically, McKenzie and Mikkelson's event rarity theory argues that probabilistically rare observations are more informative to the perceiver than "common" observations. Rarity, in this case, is defined in terms of log likelihood ratios (i.e., the ratio of the probability of an observation given a correlated population to the probability of an observation given an uncorrelated population; see also Anderson, 1990). In simpler terms, people hold beliefs or expectations about the occurrence and non-occurrence of events in the environment. The occurrence of an event is rare if one's expectations indicate that the non-occurrence of the event is more likely. Alternatively, the non-occurrence of an event is rare if your expectations indicate the occurrence of the event is more likely. If the occurrence (or presence) of two events are less likely than the non-occurrence (or absence) of those events, then the observation of co-occurrence is the rarest observation possible (i.e., given that the other possibilities are co-nonoccurrence, and the occurrence of one event and

not the other) and, ultimately, the most informative. To illustrate, consider the following scenario: McKenzie and Mikkelson used the variables “mental health” and “high school graduate” the levels of which were “presence” and “absence.” Based on prior beliefs about the environment, one arguably should expect a randomly selected person in the population to be both mentally healthy (mental health – present) and a high school graduate (high school graduate – present). In this case, co-occurrence is expected, thus, common, and co-nonoccurrence (i.e., the randomly selected person is neither mentally healthy or a high school graduate) is unexpected, thus rare. McKenzie and Mikkelson argue that if event rarity is the driving force behind a bias for Cell A information, then a Cell D bias should be demonstrated when the variable level of absence is less common than the presence of the variables (i.e. it is more common for an event to occur than for that event not to occur). In other words, they hypothesized that by manipulating the rarity of presence and absence of events, a preference for Cell A would be reversed to that for Cell D.

McKenzie and Mikkelson (2007) tested the event rarity hypothesis by presenting participants with scenarios in which “presence” was rare as well as scenarios in which “absence” was rare. They hypothesized that in situations where absence was rare, bias for joint-present information (Cell A observations) would be reversed to a bias for joint-absent information (Cell D observations). To test this, they manipulated the rarity of an observation (joint presence or joint absence) by adjusting the language used in the scenario. Specifically, in one of the scenarios, presence was rare when the variables were “high school drop-out” and “mental illness”, and the absence was rare when the variables were “high school graduate” and “mental health.” The levels of the variables in question were “presence” and “absence” as discussed above. The underlying assumption, of course, is that given an unspecified population, high school graduates are more common than high school drop outs, and similarly mental health is more common than mental illness (of course arguments could be made against this assumption). McKenzie and Mikkelson did, in fact, find support for a reversal such that the results supported a Cell A bias when presence was rare and a Cell D bias when absence was rare, but only in conditions where the variables were concrete rather than abstract.

Kelley (2007) presented participants with correlationally determinate and indeterminate hypothetical data. In the experimental task, participants were asked to review the sets of hypothetical data and rank order the samples with respect to the likelihood that the causal candidate produced the effect in the sample. The probability of each sample being drawn from a correlated versus an uncorrelated population was calculated. In most conditions, participants' behavior was reflective of these objective probabilities. Participants showed differential treatment of the two types of correlationally indeterminate data samples such that participants ranked the samples in which the causal candidate was present on each observation (indeterminate-present) consistent with the objective probabilities whereas participants did not rank the samples in which the causal candidate was absent (indeterminate-absent) on each observation as such. No clear data pattern emerged for treatment of the indeterminate-absent samples. Similarly, in an additional study by Kelley et al. (2007), the results showed that participants were sensitive to the ratio of observations in Cell A to Cell B for indeterminate-present samples, but were not sensitive to the ratio of observations in Cell C to Cell D for indeterminate-absent samples (figure 2).

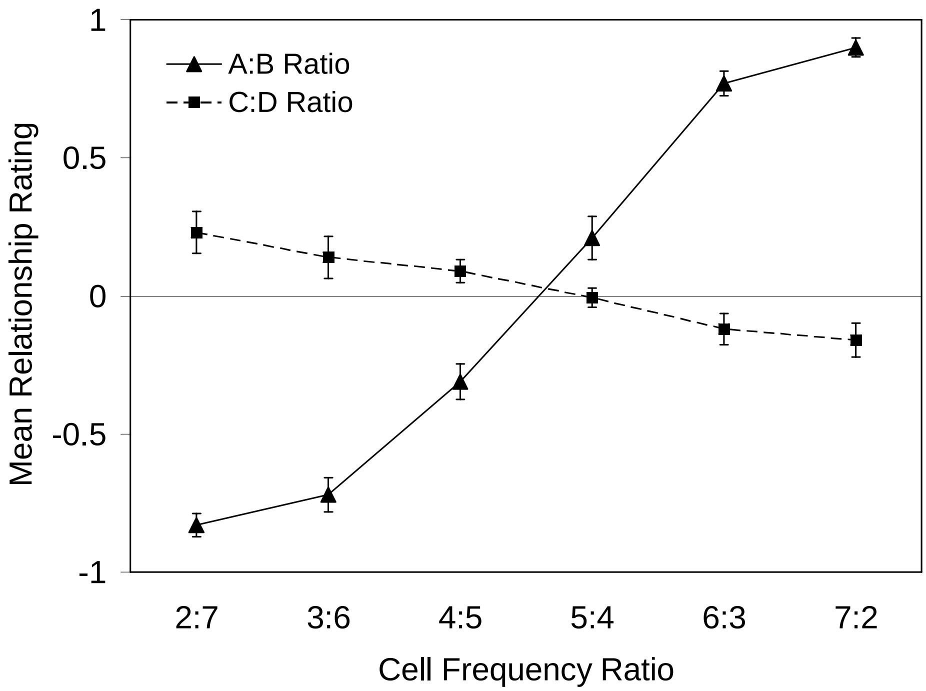

Figure 2. The mean relationship ratings as a function of the A:B or C:D ratio of cell frequencies in Kelley et al. (2007). A:B pertains to the indeterminate-present condition; C:D pertains to the indeterminate-absent condition. Error bars represent the standard errors of the means.

Figure 3 displays the results from Kelley (2007). For the indeterminate-present samples, participants' rankings reflected the objective probabilities that were previously determined in a statistical simulation. The objective probabilities represent the likelihood that each particular sample was drawn from a correlated population and from an uncorrelated population (i.e., the probability that a sample of six Cell A observations and two Cell B observations would be drawn from a positively correlated population versus an uncorrelated population). Specifically, the probability of an indeterminate-present with 6 Cell A and 2 Cell B observations (Ip 6:2) drawn from a correlated population is greater than that drawn from an uncorrelated population. Participants highly ranked Ip 6:2 samples thus indicating that the sample showed strong evidence of a relationship between x and y. In other words, for indeterminate-present samples, when the probability that the sample came from a correlated population was high, participants ranked the sample high and when the probability that the sample came from an correlated population was relatively low, participants ranked the sample low. This finding is illustrated in figure 3. However, also shown in figure 3, participants' mean ranks for the indeterminate-absent samples were roughly equal for both types of indeterminate-absent samples despite the large difference in objective probabilities for the two types. Thus, the mean ranks for indeterminate-absent samples did not reflect the objective probabilities.

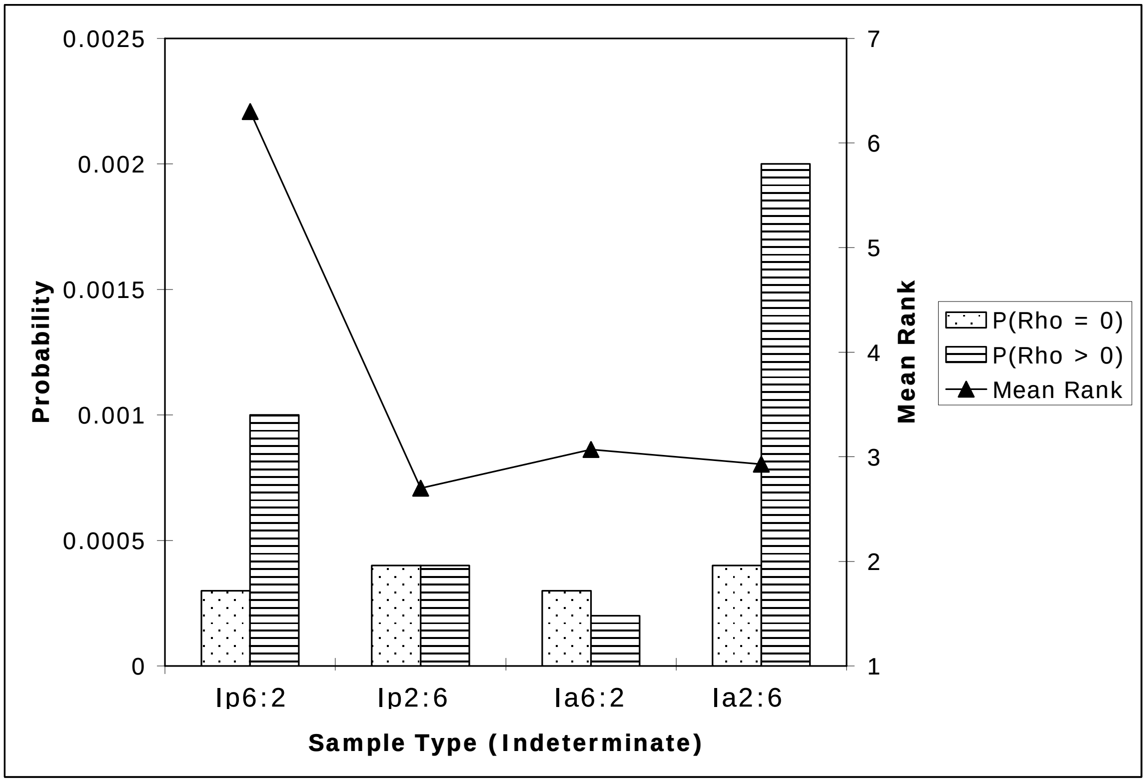

Figure 3. Data from Kelley (2007). Mean rank results plotted against the simulation results (probabilities of each indeterminate sample type being drawn from correlated and uncorrelated populations). Sample types are denoted as indeterminate-present with a Cell A to B ratio of 6:2 (Ip6:2), indeterminate-present with a Cell A to B ratio of 2:6 (Ip2:6), indeterminate-absent with a Cell C to D ratio of 6:2 (Ia6:2), and indeterminate-absent with a Cell C to D ratio of 2:6 (Ia2:6).

Kelley (2007) suggested that the difference in results between indeterminate-present and indeterminate-absent samples may be explained by the previously described event rarity theory. In Kelley's study, the indeterminate-present samples only included observations where the causal candidate was present and the indeterminate-absent samples only included observations where the causal candidate was absent. In both sample types, the effect varied. Event rarity would predict no effect of cell ratio in the indeterminate-absent samples. Specifically, given that the sample lacks rare observations, the sample may not be informative enough for the decision maker to be sensitive to the probability of the sample being drawn from a correlated versus uncorrelated population.

Research questions

The present study was designed to further evaluate and test predictions of the event rarity hypothesis in varying conditions including correlationally indeterminate samples. The main research question was whether participants would not provide biased responses when the occurrence of a variable was equally likely as the non-occurrence. This question and sub-questions are described in more detail below.

Symmetric variables

Given that McKenzie and Mikkelson (2007) found a reversal of bias from Cell A to Cell D when co-nonoccurrence (joint absence) was rare, the present study tested whether no bias would be demonstrated under certain conditions. Specifically, if the variable levels are symmetric, then one level of the variable is equally as likely as the other level, thus, the event rarity theory would predict that no bias be demonstrated for either Cell A or D.

Correlationally indeterminate data

Kelley et al. (2007) have previously given participants samples with an indeterminate correlational relationship and asked them to judge the causal relationship between the variables. Specifically, two types of indeterminate samples were presented; indeterminate-present samples where the causal variable was present on each observation in the sample and indeterminate-absent where the causal variable was absence on each observation in the sample. Also, the ratio of Cell A to Cell B observations (for indeterminate-present samples) and the ratio of Cell C to Cell D observations (for indeterminate-absent samples) were varied in these studies. The authors found that there was a strong effect of cell ratio for the indeterminate-present samples and little to no effect in the indeterminate-absent samples. As mentioned above, the event rarity theory would predict the null effect of cell ratio because indeterminate-absent samples may not provide enough information. However, previous research has suggested that participants struggle with reasoning about "absent" information (Wason & Johnson-Laird, 1972). This leads to the second research question in this study which addressed whether the null effect of cell ratio in the indeterminate-absent samples is a reflection of the lack of rare (informative observations) or difficulties with reasoning about "absent" information on the part of the participant. The event rarity theory would predict that a strong data pattern would emerge when the indeterminate sample contains "rare" observations and a weak or null effect when the indeterminate sample contains "common" observations. Alternatively, if responses are a consequence of difficulties processing absent information, then the results should show a weak or null effect of cell ratio in the indeterminate-absent samples.

Event rarity manipulation

Finally, the study tested whether event rarity can be manipulated without changing the variable labels, suggesting that McKenzie and Mikkelson's (2007) results supporting the event rarity hypothesis could be explained as a framing effect (ie. systematic change in responses resulted from the positive/negative frame of the question). In the present study, the variable

labels are constant across conditions while the cover story varies with respect to the group that the data describes. The three groups were chosen with respect to stereotypes and beliefs about those groups.

Research objective

The objective of this study was to evaluate the role of event rarity in the perception of correlationally indeterminate data.

Methods

General

The study protocol was approved in advance by the Bowling Green State University Human Subjects Review Board (HSRB) and informed consent was obtained. The study attempted to produce a reversal of bias using correlationally indeterminate samples varying two levels of cell ratio and by manipulating event rarity with respect to the subpopulation described in the instructions. This is a 3 (group membership) X 2 (indeterminate sample type) X 2 (cell ratio) between-subjects design thus yielding 12 conditions.

Participants

Participants were 163 students enrolled in an Introduction to Psychology course at a Midwestern university. They did not receive any compensation for participation.

Procedure

Participants completed a paper and pencil covariation assessment task. The task instructions stated that they were to look at a sample of data gathered in a hypothetical study of gender and personality traits. The two variables in the data were gender, the levels of which were male and female, and personality trait, the levels of which were selfish and generous. Since the levels of the variables were not presence and absence, the contingency table was labeled such that Cell A corresponded to observations where gender was female and trait was generous, Cell B where gender was female and trait was selfish, Cell C where gender was male and trait was generous, and Cell D where gender was male and trait was selfish (figure 4).

After reading the instructions and cover story, participants saw one sample of eight observations in a summary format. An example of the task is included in the appendix. Participants saw one of four possible sample types: indeterminate-AB with a cell ratio of 6:2, indeterminate-AB with a cell ratio of 2:6, indeterminate-CD with a cell ratio of 6:2, or indeterminate-CD with a cell ratio 2:6. In indeterminate-AB samples, the level of gender was always female and in indeterminate-CD samples, the level of gender was always male. A cell ratio of 6:2 indicates six Cell A and two Cell B (or six Cell C and two Cell D) observations in the

sample whereas a cell ratio of 2:6 indicates two Cell A and six Cell B (or two Cell C and six Cell D). After viewing the sample, participants were asked to rate the relationship between gender and trait on a scale of 0 to +10. Finally, participants ranked the four possible observations from 1 to 4 with 1 being the most informative and 4 being the least informative.

Group membership

One third of the participants were told that the hypothetical study surveyed nurses, which is commonly believed to be a job held by more women than men and implies generosity, thus in this condition Cell A (generous, female) was common and Cell D (selfish, male) was rare. One third were told that the study surveyed politicians, which is a stereotypically male dominated field and has negative connotations such as selfishness, thus in this condition Cell A (generous, female) was rare and Cell D (selfish, male) was common. The final third of participants were told that the study surveyed hotel managers, which is not stereotypically gender specific or personality trait specific, thus in this condition Cell A (generous, female) should be equally likely as Cell D (selfish, male). An informal survey supported these stereotypical, social beliefs about the variables in question.

		Trait	
		Generous	Selfish
Gender	Female	A	B
	Male	C	D

Figure 4. Contingency table describing variables used in study.

Results

Six of the 163 participants were excluded from the analyses because they did not follow the instructions properly thus leaving 157 participants in the analyses. Mean ranks were calculated for each observation type and displayed in the Figure 5. However, given the dependent nature of the ranking task, a Chi-square test was used to summarize and analyze this data. The proportion

of times that Cell A and the proportion of times that Cell D were ranked as the most informative were calculated for each condition (see table). This data suggests that there is a preference for Cell D when the sample is indeterminate-CD and the ratio is 2:6 regardless of subpopulation type. Alternatively, Cell A is ranked as the most informative when the sample is indeterminate-AB and the ratio is 6:2. The rarity manipulation seemingly did not influence these data as predicted.

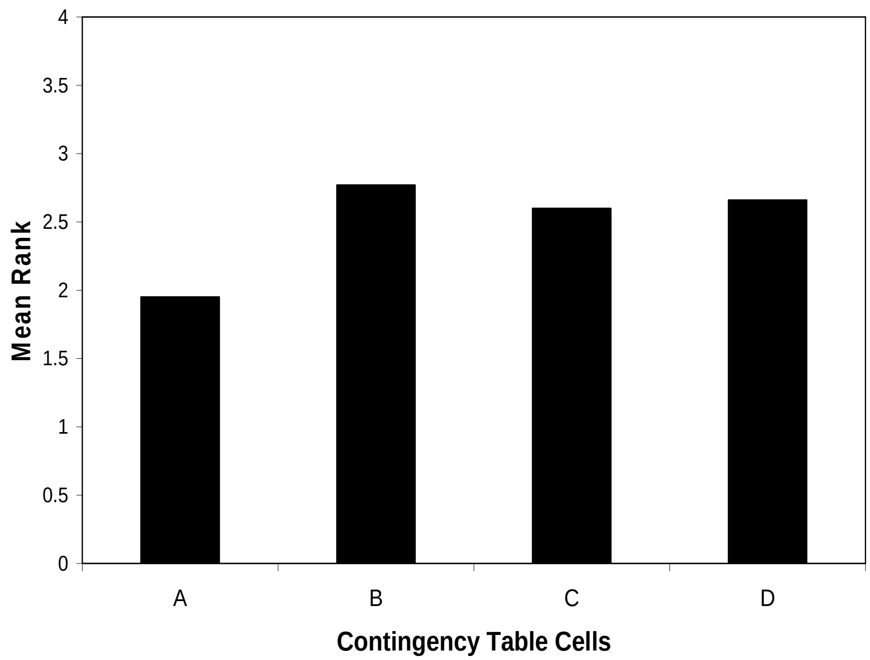

Figure 5. Mean ranks for each contingency table cell. The cells were ranked from 1 (most informative observation) to 4 (least informative observation).

Table

Proportions of times Cell A and Cell D were ranked most informative.

Ratio Type	Ind. Type	Rarity Type	*n*	Prop. Cell A	Prop. Cell D
6:2	Ind-AB	Cell D rare	14	0.857	0.143
2:6	Ind-AB	Cell D rare	12	0.167	0.167
6:2	Ind-CD	Cell D rare	12	0.417	0.00
2:6	Ind-CD	Cell D rare	15	0.52	0.533
6:2	Ind-AB	Cell A rare	13	0.846	0.154
2:6	Ind-AB	Cell A rare	13	0.385	0.077
6:2	Ind-CD	Cell A rare	13	0.308	0.154
2:6	Ind-CD	Cell A rare	16	0.25	0.625
6:2	Ind-AB	Equally Likely	14	0.714	0.071
2:6	Ind-AB	Equally Likely	12	0.167	0.00
6:2	Ind-CD	Equally Likely	11	0.455	0.00
2:6	Ind-CD	Equally Likely	12	0.25	0.50

Note. Indeterminate sample types are denoted Ind-AB (indeterminate-AB) and Ind-CD (indeterminate-CD).

In this study, participants rated the relationship between two dichotomous variables on a scale from 0 (no relationship) to +10 (perfect relationship) after viewing a summary format sample of data. To analyze the data, a 3 (group membership) X 2 (indeterminate sample type) X 2 (cell ratio) between-subjects Analysis of Variance (ANOVA) was used. There was a significant main effect of cell ratio emerged such that when the ratio was 2:6 the relationship was rated higher than when the ratio was 6:2, F (1, 148) = 4.05, p = .046. There was also a significant interaction between subpopulation and indeterminate sample type, F (2, 148) = 5.3, p = .006, in that when Cell A was the rare observation (the surveyed group was politicians), indeterminate-AB samples were rated higher than indeterminate-CD. When Cell A and Cell D are equally likely (the surveyed group was hotel managers), then indeterminate-AB samples were rated lower than indeterminate-CD samples. When Cell D was the rare observation (the surveyed group was nurses), indeterminate-AB samples were similarly rated to indeterminate-CD samples. The results are summarized in figures 6, 7, and 8. This interaction is difficult to interpret, however, suggests that participants' ratings may also reflect the degree of confidence in that rating. Specifically, when Cell A was rare and participants saw a sample with Cell A observations, this may have increased their confidence in the rating thus rating it higher than samples that did not contain Cell A observations.

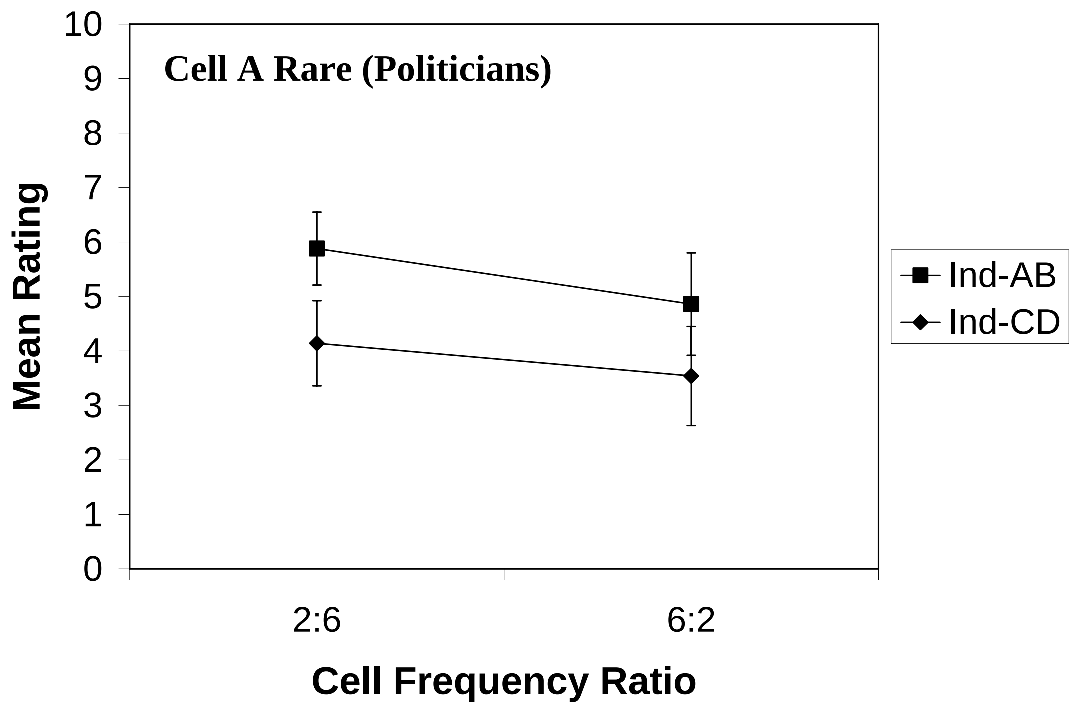

Figure 6. Mean relationship ratings when Cell A is the rare observation. Sample types are indeterminate-AB and indeterminate-CD, denoted Ind-AB and Ind-CD respectively. Cell ratios were 2:6 and 6:2. Bars represent standard error of the mean.

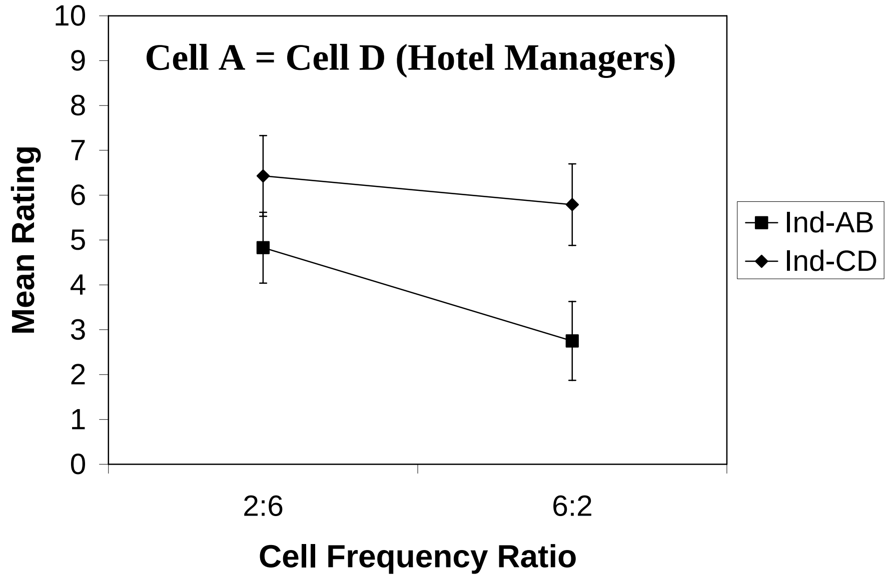

Figure 7. Mean relationship ratings when Cell A and Cell D observations are equally likely. Sample types are indeterminate-AB and indeterminate-CD, denoted Ind-AB and Ind-CD respectively. Cell ratios were 2:6 and 6:2. Bars represent standard error of the mean.

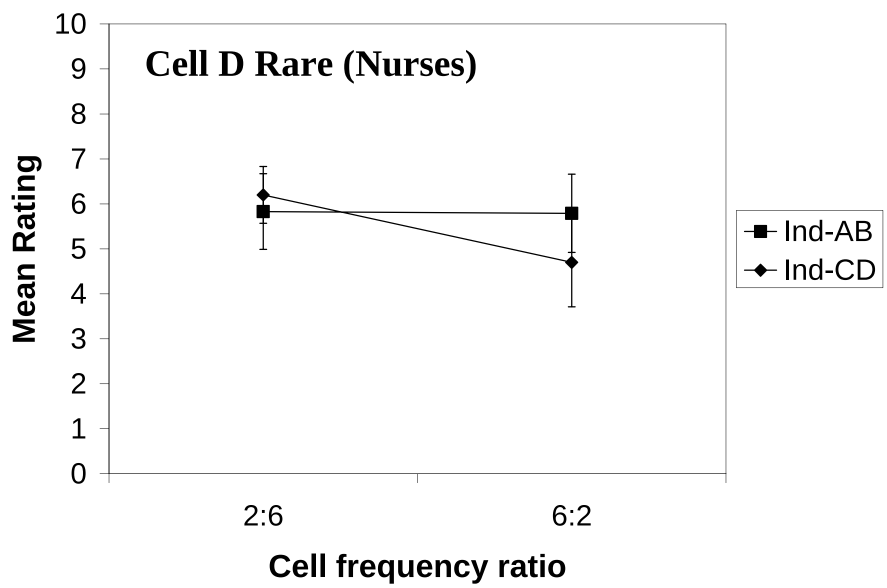

Figure 8. Mean relationship ratings when Cell D is the rare observation. Sample types are indeterminate-AB and indeterminate-CD, denoted Ind-AB and Ind-CD respectively. Cell ratios were 2:6 and 6:2. Bars represent standard error of the mean.

Discussion

The results do not support the event rarity hypothesis, however, they do suggest that under some conditions behavior may be consistent with confirming hypothesis testing behavior. Klayman and Ha (1987) described positive test strategy as testing a hypothesis by selecting and attending to observations where the effect is expected or has occurred. By this definition, it could be argued that participants in this study were giving preferential weight to observations that confirmed their expectations. For example, when participants were told that the hypothetical study surveyed nurses, the expectation is for generous females rather than selfish males. In other words, the "common" observation is also the expected observation and actual observations of generous females only reaffirmed those expectations. There is moderate evidence of this in the results such that when Cell A observations were "common" or expected, participants rated samples with a high frequency of Cell A observations (indeterminate-AB with a cell ratio of 6:2) higher (i.e., stronger support of a relationship) than samples with a relatively low frequency of Cell A observations (indeterminate-AB with a cell ratio of 2:6). Likewise, when Cell D observations were "common," participants rated samples with a high frequency of Cell D observations (indeterminate-CD with a cell ratio of 2:6) higher than those with a relatively low frequency (indeterminate-CD with a cell ratio of 6:2). In other words, participants indicated that the "common" observations were most informative, whereas the event rarity hypothesis predicts just the opposite. It should be noted that these effects were weak.

The current study presented participants with symmetrical variables thus eliminating the use of the variable levels "presence" and "absence." Given this, the labeling of the contingency table is arbitrary (i.e., the contingency table could have been adjusted so that Cell A observations were selfish males and Cell D observations were generous females). However, a large proportion of participants still ranked Cell A observations as the most important data, even when the sample did not contain any Cell A observations. The reason for this is unclear. It is possible however, that this could also be explained by Klayman and Ha's (1987) positive test strategy which states that expected events and outcomes are given preferential attention in hypothesis testing. In this study there are four possible observations; generous females, selfish females, generous males, and selfish males. Despite the group (nurses, politicians, hotel managers) presented in the instructions or cover story, participants may have the expectation that females are generous. Therefore, this observation is the most important to the participant despite the details of the group involved in the hypothetical study or the actual sample observed, thus resulting in Cell A observations being ranked as the most informative by a large proportion of participants.

The results of the current study seem to be more consistent with positive test strategy than the event rarity hypothesis. One reason for this may be that the social beliefs and stereotypes invoked by the groups may not have been sufficient to manipulate event rarity given that the biases demonstrated do not reconcile with event rarity theory. Rather, the stereotypes may have only brought forward expectations thus yielding results consistent with positive test strategy.

Another reason may be that participants were unclear about how to proceed with the task. Three participants reported that they did not have enough information to make the judgment with

any degree of confidence. In other words, these participants guessed the answer. There could have been a number of other participants who merely guessed the answer without providing any indication of such.

One final reason may be the use of symmetrical variables rather than asymmetric variables with the levels of “presence” and “absence.” The stereotypes and social beliefs concerning the groups may not have elicited the artificial asymmetry as intended. If so, then participants may have inferred the likelihood of each observation to be equal thus leading them to use an alternate method to approach the task (i.e., positive test strategy).

Future studies

As previously discussed, event rarity theory predicts the previously reported data patterns in the relationship ratings of correlationally indeterminate samples. In a future study, participants will be presented with indeterminate samples describing a causal candidate and effect, the levels of which are to be “presence” and “absence.” The labels of the causal candidate and effect will vary such as to be consistent with McKenzie and Mikkelson (2007). The goal of this future project is to replicate a reversal of effects from indeterminate-present to indeterminate-absent samples given the respective likelihood of the “presence” and “absence” of both variables in question. If the results of the future study do, in fact, support the event rarity theory then that would suggest the applicability of event rarity to the perception of correlationally indeterminate samples. This would further support the conclusion of this current study that the social beliefs rarity manipulation was insufficient to evoke a reversal of bias.

Conclusions

The objective of the present study was to evaluate the role of event rarity in the perception of correlationally indeterminate data. Given the results of previous research on correlationally indeterminate data, it was predicted that participants’ responses would indicate “rare” observations to be the most informative and for this to also be reflected in the correlational relationship ratings of the samples presented. Participants showed a bias for “common” observations rather than “rare” observations, however, thus not providing support for the event rarity hypothesis. As previously discussed, some of the results are consistent with positive test strategy. Further research is ongoing to evaluate the event rarity hypothesis and positive test strategy in relation to correlationally indeterminate data and which factors may drive differential behavior (e.g., preference for “common” observations over “rare” ones and vice versa).

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Appendix

Trial sample

Instructions:

One hundred NURSES were asked to participate in an experiment studying gender and personality. Each participant's personality was determined by a survey.

Below, you will see a small sample of the experiment's data. For each participant, you will be told whether the participant is MALE or FEMALE and whether the participant is characterized as being GENEROUS or SELFISH. After viewing the data, please answer the following questions.

Participant #:	Gender:	Personality Trait:
6	Female	Generous
57	Female	Selfish
3	Female	Selfish
8	Female	Generous
21	Female	Generous
23	Female	Generous
80	Female	Generous
22	Female	Generous

Questions:

For the 100 Nurses who participated, how strong is the relationship between gender and whether their personality is generous or selfish.

Please rate the relationship between 0 and +10 using the scale below:

0 NO RELATIONSHIP
+10 STRONG RELATIONSHIP

Rating:__________________________________

Regardless of which kinds of observations are shown in the data table (above), rank the following kinds of observations in terms of how strongly they would support evidence of a relationship (Place a letter in each blank):

(A) Female and Generous (B) Female and Selfish
(C) Male and Generous (D) Male and Selfish

#1 (strongest support) ____
#2_____
#3_____
#4 (weakest support) _____

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